X-ray Tube Adaptation: Why and When?

Basics:

Filaments become thinner during the lifetime of a tube. Filament lifetime is related to the application and system the tube is in. At higher filament temperatures, the white-hot tungsten wire evaporates more.

If installed in a system for fluoroscopy only (no exposures), the filament will not age at all since the filament current will hardly exceed 3.5 or 4.5A, depending on the filament type. This is also the case for tubes which are mainly used for tomography which uses only low emission currents, or in DSI systems which use fixed mA technique.

However, in applications using low kV levels and AEC (kV-Amplimat), or kV-mAs techniques to achieve the shortest exposure time with the highest possible mA value, filament currents are more or less at their limits (see Appendix A for emission and filament curve examples of the SRO33/100).

The lifetime of a filament also decreases if the preparation time is very long, since the filament is then at exposure temperature. Longer preparation times are usually required at children's hospitals or Accident & Emergency rooms. The average preparation time for an exposure in a routine room might be about 3 seconds, children's and A&E rooms sometimes require up to 10 seconds.

Generators such as SCP, Optimus CP (Power Part), Medio CP and Optimus RAD - R/F - C have a current source as filament circuit. Once exposure data are selected the generator sets a filament current (at PREP) to achieve the required emission current. The filament current is taken from the tube data table which was stored during the last adaptation.

SCP generators and Optimus power parts use standard tube type data (kV dependent filament <=> emission current characteristic) as programmed in the PROMs. During adaptation the deviations of the actual tube to the default tube type data are stored in the memory.

Optimus RAD - R/F - C generators use only default tube limit data. Exposures are made at many defined filament currents at different kV stages, and a big array of emission current values (the adaptation data table) is then stored during adaptation to get the individual kV-dependent filament - emission current characteristic of the installed tube within the given limits.

The filament constantly gets thinner during its operational lifetime. The filament circuit will maintain the same filament current which is in the table for a certain kV-dependent emission current. As a result the filament temperature will rise, as the current will have to pass a smaller cross section of the wire.

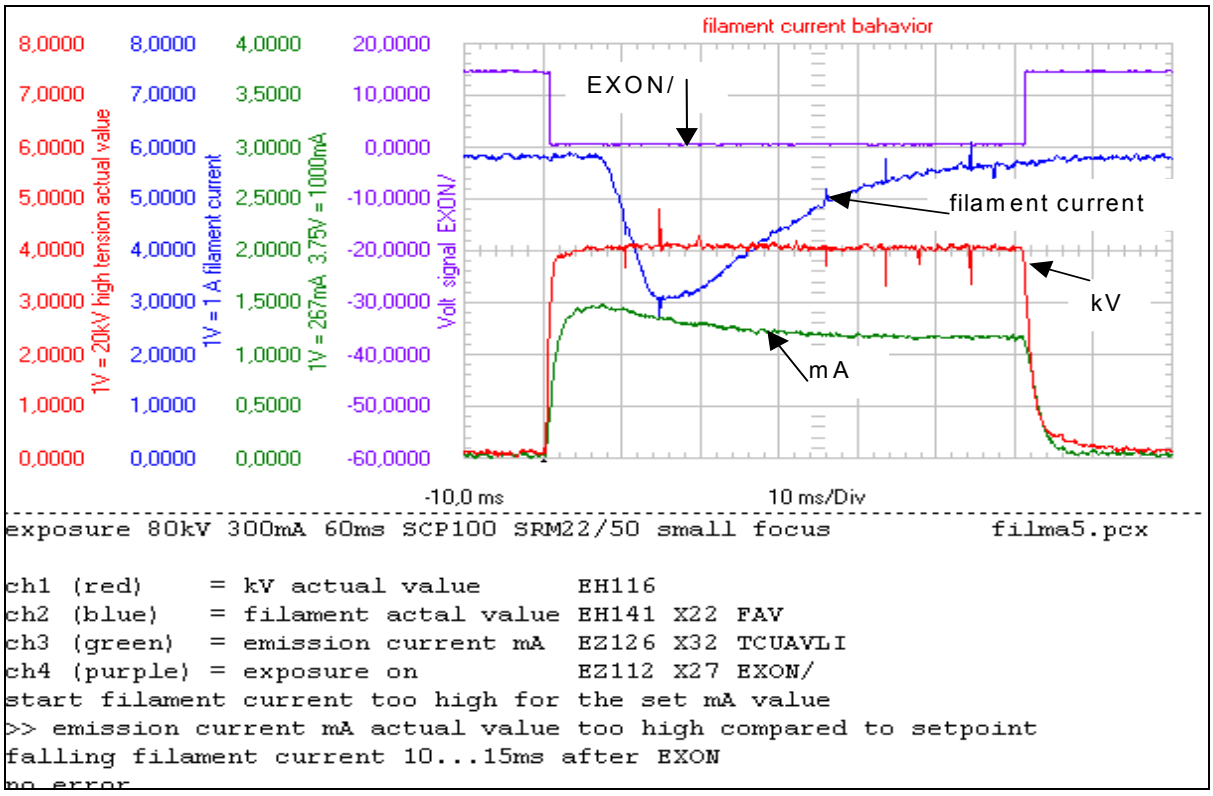
The emission current also increases with the rising temperature. The output power can rise dramatically, e.g. from 80kW to > 100kW. This may cause one or more of the following problems: deviations in density (non-AEC technique SCP and MedioCP), emission current error codes, mAs deviation errors, limit overflow errors and/or mains breaker tripping.

The decision to re-adapt or not (e.g. during planned maintenance) should depend upon the:
- error codes logged
- number of exposures (total or if recorded between the PM periods)
- application (pediatric room, A&E, low kV/high mAs)
- filament current behavior, monitored with an oscilloscope according to the following examples.

Tubes are often adapted when a pre-installed system gets into operation. **This is not necessary**. Only condition the tube, especially when a long time has passed between shipping and installation.

SCP

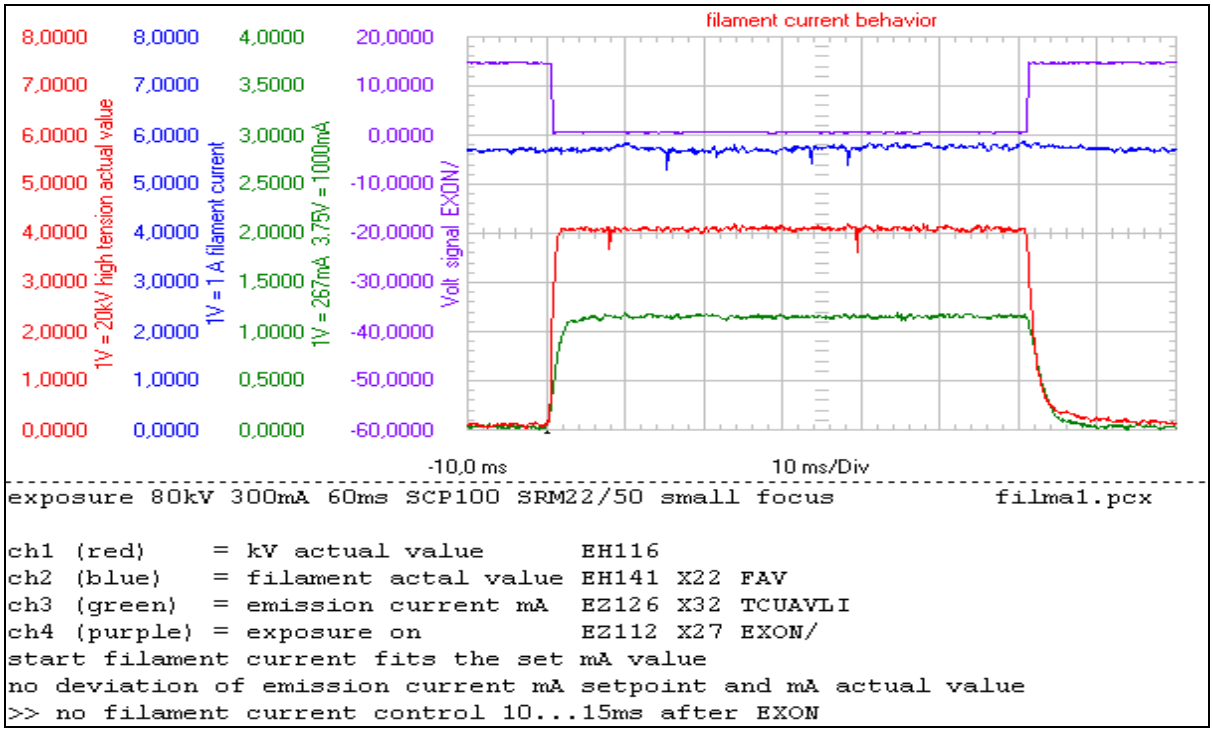
The following screenshot of an SCP displays what happens if there was no re-adaptation for a long time, or after many exposures and/or long preparation times.
Check the exposure counter(s) service mode 6.2 (and 6.3).




```
exposure 80kV 300mA 60ms SCP100 SRM22/50 small focus          filma5.pcx

ch1 (red)     = kV actual value       EH116
ch2 (blue)    = filament actal value EH141 X22 FAV
ch3 (green)   = emission current mA  EZ126 X32 TCUAVLI
ch4 (purple) = exposure on           EZ112 X27 EXON/
start filament current too high for the set mA value
>> emission current mA actual value too high compared to setpoint
falling filament current 10...15ms after EXON
no error
```

This filament must be re-adapted and it will lead to the following result:


filament current behavior
1V = 20kV high tension actual value
1V = 1 A filament current
1V = 267mA 3.75V = 1000mA
Volt signal EXON/
-10,0 ms
10 ms/Div

```
exposure 80kV 300mA 60ms SCP100 SRM22/50 small focus          filma1.pcx

ch1 (red)     = kV actual value       EH116
ch2 (blue)    = filament actal value EH141 X22 FAV
ch3 (green)   = emission current mA  EZ126 X32 TCUAVLI
ch4 (purple) = exposure on           EZ112 X27 EXON/
start filament current fits the set mA value
no deviation of emission current mA setpoint and mA actual value
>> no filament current control 10...15ms after EXON
```

After adaptation the emission current of 300mA is driven by a filament current of 5.6A instead of 5.8A as before.

Another quick method (using an mAs meter) can be carried out if an oscilloscope is not present:

- Set kV-mAs with e.g. 80kV any focus.
- Set an mAs value which results in an exposure time of max 20ms (for small and large focus).
- Hook up the mAs meter and compare the set mAs value against the measured one.
- SCP generators terminate exposures by the timer, not by the mAs value.
- If the measured mAs value is higher compared to the setpoint re-adapt.

If no measuring tool at all is present carry out an audible check:

- Same technique as above, but increase the mAs value to get an exposure time of 100 - 150ms.
- Switch the exposure.
- If the converter frequency decreases during the exposure the focus must be re-adapted.
Reason: The emission current results in a certain converter frequency. Once the tube current regulator EZ126 decreases the filament current the converter frequency also decreases with the sinking mA and load.

Error codes like 3961 (mA measured > 30% mA set), 3512 (mAs deviations) , 3275 (emission current deviation > 40%) will be the ones which might indicate that the filament(s) require a re-adaptation.

It might happen that adaptation fails if the actual filament condition is far out of the tolerance of the default tube data. A typical indication is that the mA post indication values jump back and forth between almost zero and unusual high values. It is therefore advisable to download the CMOS before starting adaptation as a safety backup.

Note: SCP generators can principally operate without tube adaptation by resetting error 3712 and running the tube with the default PROM data. Just check the filament current behavior as on the page before.

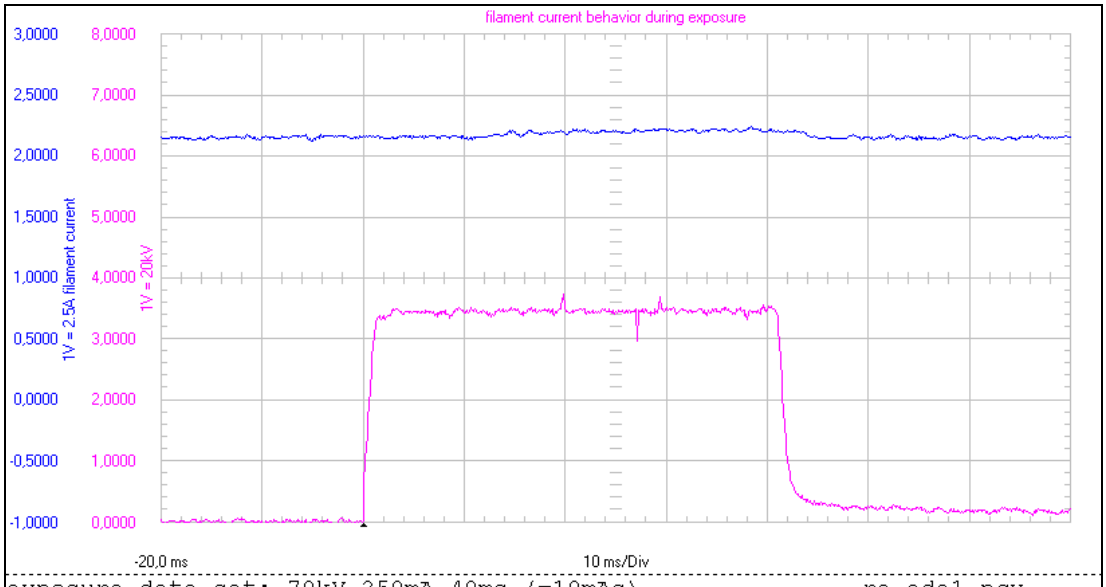
In certain cases the filament may be partly welded together so that the tube output is smaller than what it should be. The tube current regulator will then try to compensate by driving up the filament current to the filament setpoint limit (FISPLIM) value of the selected focus. Such cases are very seldom. Depending on the remaining emitting length of the filament adaptation may be possible or not, measures to be carried out are similar to those previously explained.

Optimus RAD - R/F - C

Optimus generators terminate 2/3-knob exposures by measuring the mAs, not by time.
Deviations can be monitored best with an oscilloscope, but only at the filament current actual value measuring points EZ119 X5 (small focus) and X7 (large focus).
There is too much noise at the mAs measuring point to monitor the emission current there.

Additional kV monitoring will display the actual exposure time.

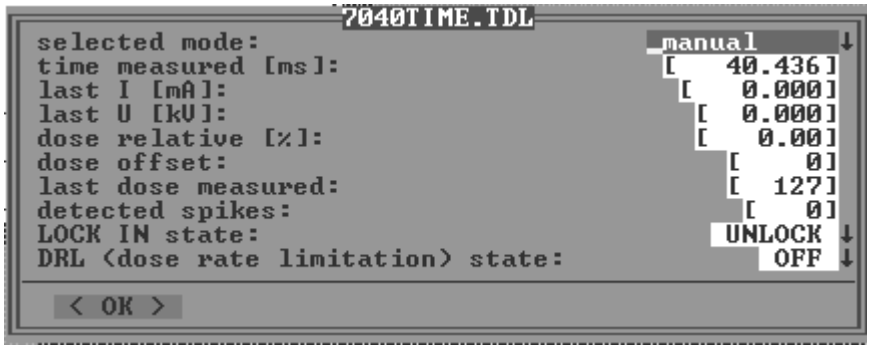
The following screenshot displays an exposure with emission current and exposure time almost at the setpoints:




```
exposure data set: 70kV 250mA 40ms (=10mAs)                re_ada1.pcx
ch A    = filament current actual value EZ119 X7 (upper signal)
ch B    = kV actual value EZ130 X3                (lower signal)
trigger = CTRL_X_C/ EZX 74 neg. slope

actual exposure time = 40.4ms (average emission current 248mA)
almost no deviation of emission current
           = nearly invisible increase of the filament current
```

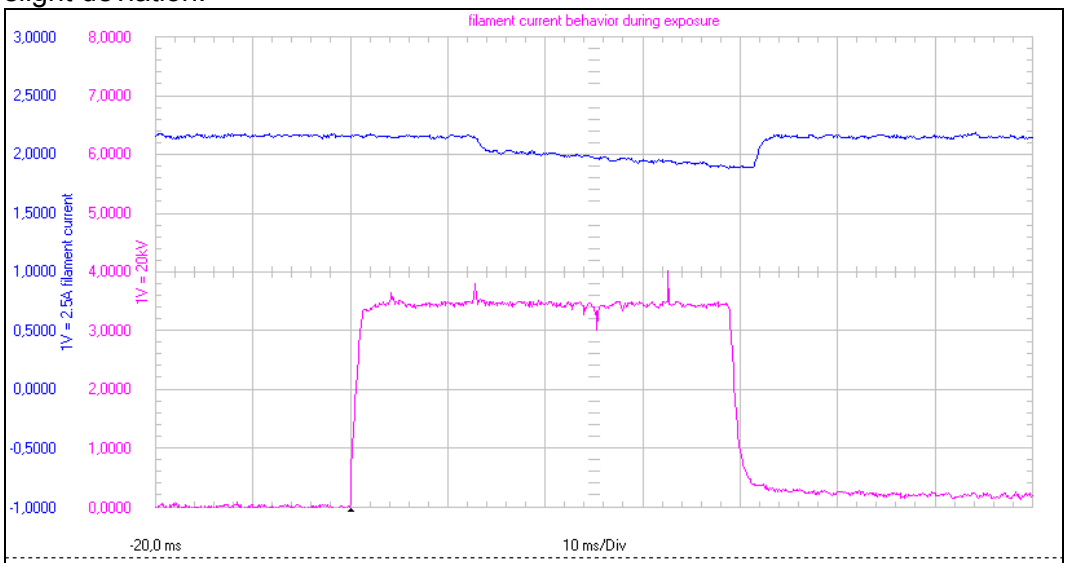
The exposure time can also be checked with the PC and XRGSCOPE:
>> Faultfind >> X-Ray Log >> Dose Rate Control Logging >> Read Actual Status


7040TIME.TDL
selected mode: manual
time measured [ms]: [40.436]
last I [mA]: [0.000]
last U [kV]: [0.000]
dose relative [%]: [0.00]
dose offset: [0]
last dose measured: [127]
detected spikes: [0]
LOCK IN state: UNLOCK
DRL (dose rate limitation) state: OFF
< OK >

If the start mA value is higher than the setpoint because of a thinner filament, the exposure time will decrease, since the counted mAs on mA-control EZ119 will be reached sooner.

The following three examples show what is visible for various filament states:

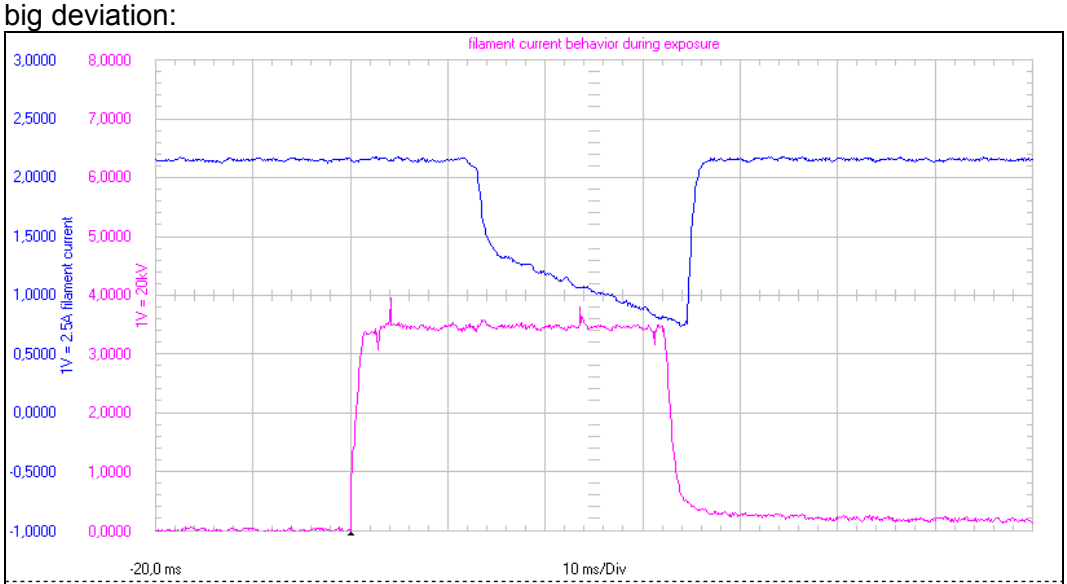
slight deviation:




```
exposure data set: 70kV 250mA 40ms (=10mAs)            re_ada2.pcx
ch A    = filament current actual value EZ119 X7 (upper signal)
ch B    = kV actual value EZ130 X3                (lower signal)
trigger = CTRL_X_C/ EZX 74 neg. slope

actual exposure time = 38.4 ms (average emission current 260mA)
                     = shorter than setpoint due to:
emission current actual value > setpoint
           = slight decrease of filament current
```

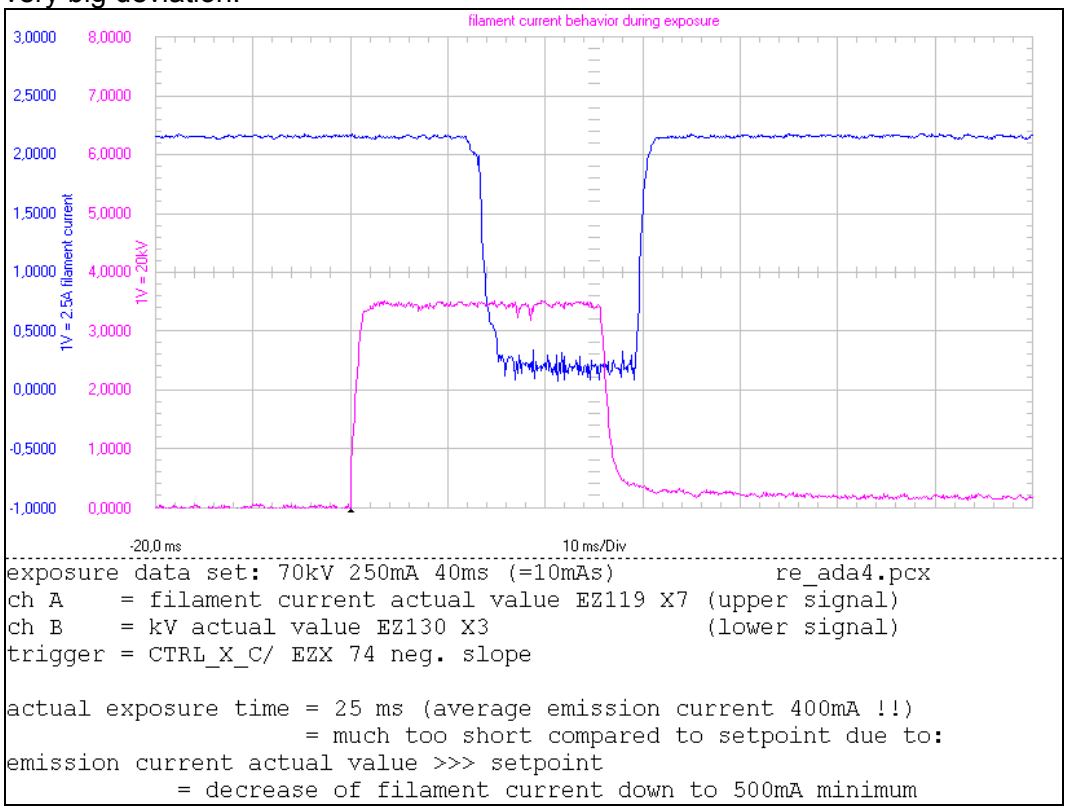
big deviation:




```
exposure data set: 70kV 250mA 40ms (=10mAs)              re_ada3.pcx
ch A    = filament current actual value EZ119 X7 (upper signal)
ch B    = kV actual value EZ130 X3                (lower signal)
trigger = CTRL_X_C/ EZX 74 neg. slope

actual exposure time = 31.7 ms (average emission current 315mA)
                     = much shorter than setpoint due to:
emission current actual value >> setpoint
           = big decrease of filament current
```

very big deviation:



The exposure times are becoming shorter with increasing emission currents.

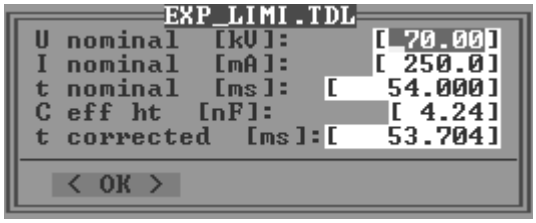
Monitoring the waveforms with an oscilloscope is the best. Hooking up an mAs meter will always get us a proper result, since mA-control terminates on mAs. A tool is required to measure the exposure time. If none is available the service PC can be used (post indication screen; see page 4).

Error codes like 03PB (emission current deviation warning logged in the background) or 03PC (emission current errors displayed at the desk) will be an indication depending on the deviation and the exposure time (see generator manual chapter 3 FAULT FINDING).

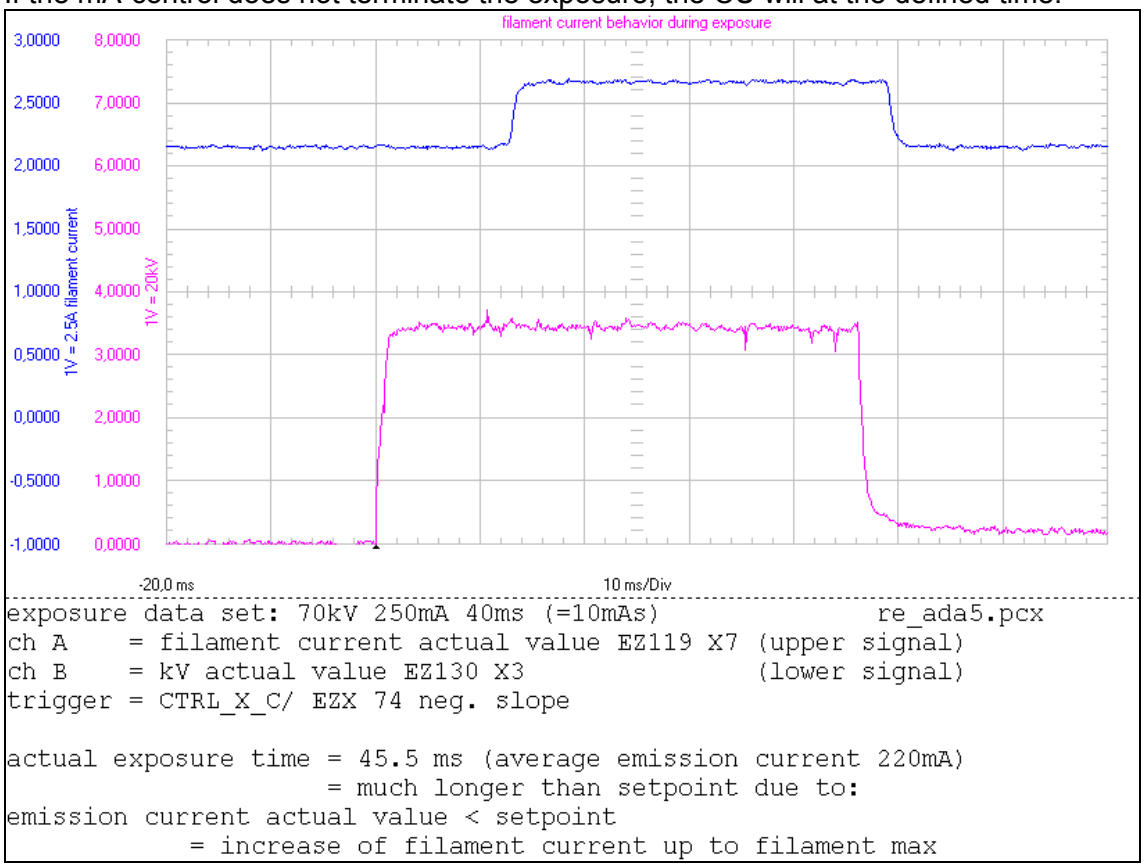
An audible converter frequency test as with SCP is not possible if no measuring tool is available.

The following screenshot could be from a partially short-circuited filament which cannot drive the proper emission current anymore.
mA-control will drive up the filament current up to its specified max value until the set mAs are achieved. The mAs values will always be as set, but the exposure times will be longer compared to the setpoint.

A certain exposure time value will not be exceeded. A max exposure time as safety backup timer is displayed at:
>> Faultfind >> X-Ray Log >> Dose Rate Control Logging >> None Automatic Technique Calculation



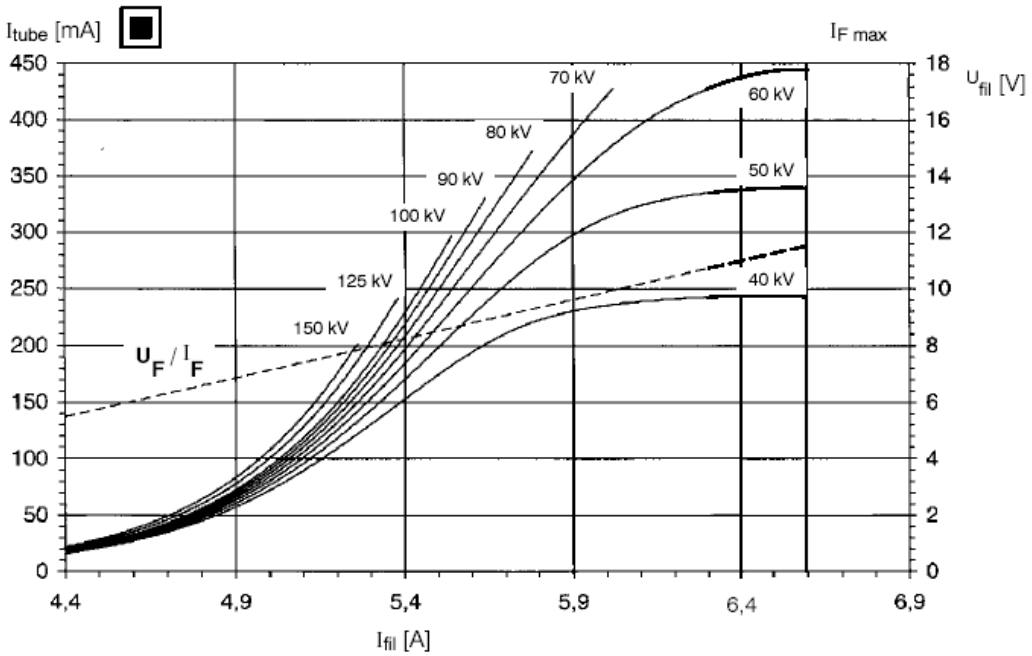
If the mA-control does not terminate the exposure, the CU will at the defined time.



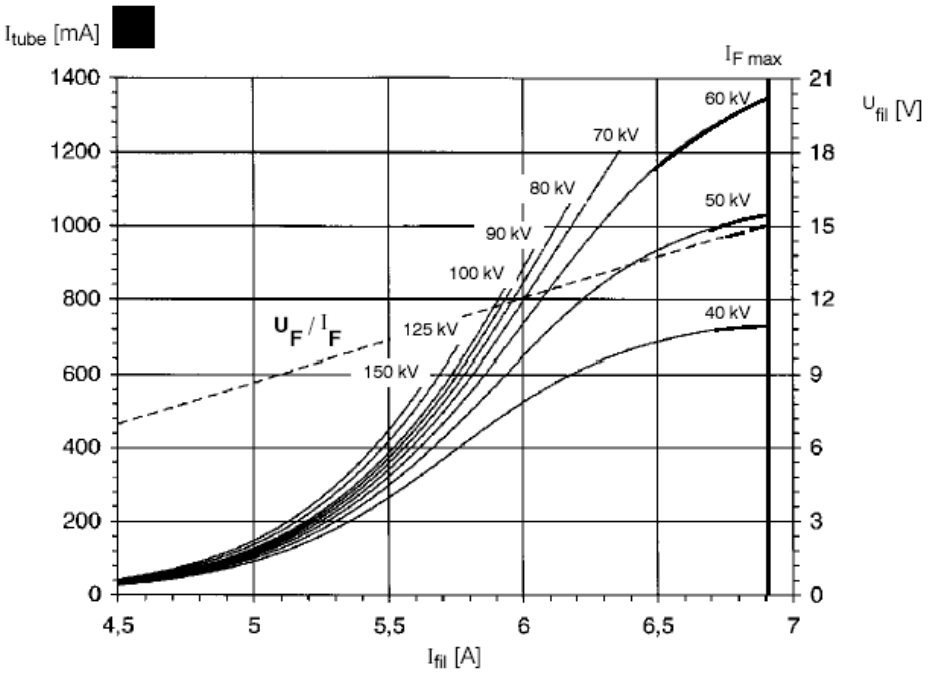
Errors 03PB and 03PC will also be logged and displayed depending on the deviation and exposure time.

It is possible to adapt a tube even if the filament emission is less than 50% of its normal value due to the Optimus adaptation method.

Appendix A



If max = 6, 26 A for new generators of OPTIMUS family with double boosting.
If max = 5, 79 A for CP - generators.



If max = 6, 74 A for generators of XRG 90 family with double boosting.
If max = 6, 49 A for CP - generators.

A4 01-06-22 Sie.
src 33100 rot 350 Z1

Emission and filament curves

SRO 33100 ROT351 (01.0) Z-1

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